Appendix A Concepts Used in Economic Analyses

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Appendix A Concepts Used in Economic Analyses

This appendix describes the concepts that are critical to understanding the economic analysis methods discussed in Chapter 3. These concepts help define the topical, temporal, and geographic scope of economic analyses.

Economic Values, Willingness to Pay, and Willingness to Accept

Although there are many ways to measure values, the use of economic values is important when choices must be made in allocating limited resources among competing programs. The theory of economic valuation is based upon individual preferences and choices. People express their preferences through the choices and trade-offs that they make, given constraints, such as those on income or time.

The economic value of a good or service to a person who is a buyer is measured by the maximum amount of other things that he or she is willing to give up in order to acquire that good or service. In a barter society, this trade-off is obvious. An example is when a person gives up three units of good A in order to obtain one unit of good B. However, in market economies, dollars (or other forms of currency) are the accepted indicator of economic value because the amount of dollars a person is willing to pay for an item indicates how much of other goods and services he or she is willing to give up for that particular item. In short, the economic value of a good to a buyer is equal to his or her "willingness to pay."

A comparable concept is called "willingness to accept" or "willingness to receive," which measures how much an individual who is a seller would accept or receive as payment if he or she could be induced to forgo a good or service. The amount of payment can then be equated to the economic value of the good or service. In short, the economic value to a seller is equal to his or her "willingness to accept." Although theoretically, willingness to pay and willingness to accept should always be equal, often they are not as shown by this example:

> A typical experiment consists of the following: a person is given an ordinary flashlight and then offered money to return it to the experimenter. The dollar amount the subject asks for is his compensation demanded (CD*) [also known as willingness to accept or WTA]*. Another person is not given a flashlight and instead is asked to pay for one. The dollar amount the subject offers is his willingness to pay (WTP). CD *[or WTA]* is usually substantially higher than WTP, by a factor of two to six times, and this disparity has been shown to occur in a variety of settings and for a wide variety of goods, including public goods."[1]

[1] John K. Horowitz, "A Test of Competing Explanations of Compensation Demanded", www.uq.edu.au/economics/johnquiggin/JournalArticles99/WTAWTPEconInq99.html

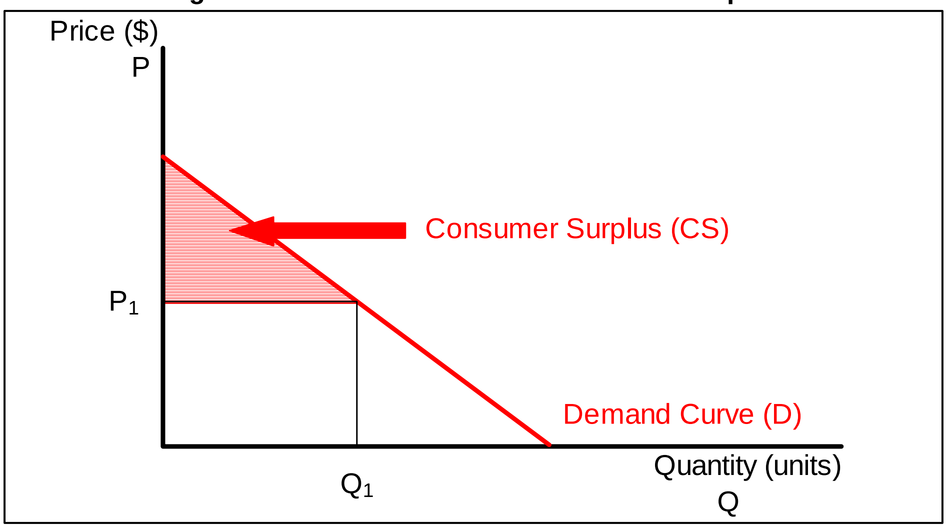
Demand Curve and Consumer Surplus

In most cases, people will purchase less of a good or service as its price increases. In economics, this is known as the "law of demand." The demand curve for a good can be illustrated by plotting the amount of a good that buyers are willing to purchase at different prices. Because the purchased quantity for a good generally decreases as the price of the good increases, the demand curve slopes downward from left to right.

In many cases people are often willing to pay more for the good, and thus their perceived value for that good, or their willingness to pay, exceeds its market price. The difference between their willingness to pay and the market price is called consumer surplus.

The derivation of demand curves requires data on the quantity purchased at different prices, plus data on other factors that might affect demand, such as income or other data. Figure A-1 illustrates the demand curve and consumer surplus for a good or service. P_1 and Q_1 indicate the current market price and the quantity purchased. The hatched area above P_1 and under the demand curve represents consumer surplus. In other words, even though the current market price of the good or service is P_1, some consumers would be willing to pay more for it. It should be noted that if a good or service has no market price (as in the case of many environmental goods and services such as flood protection or water supply services provided by wetlands), then there is no price line in Figure A-1, and consumer surplus is the entire area under the demand curve.

Figure A-1 Demand curve and consumer surplus

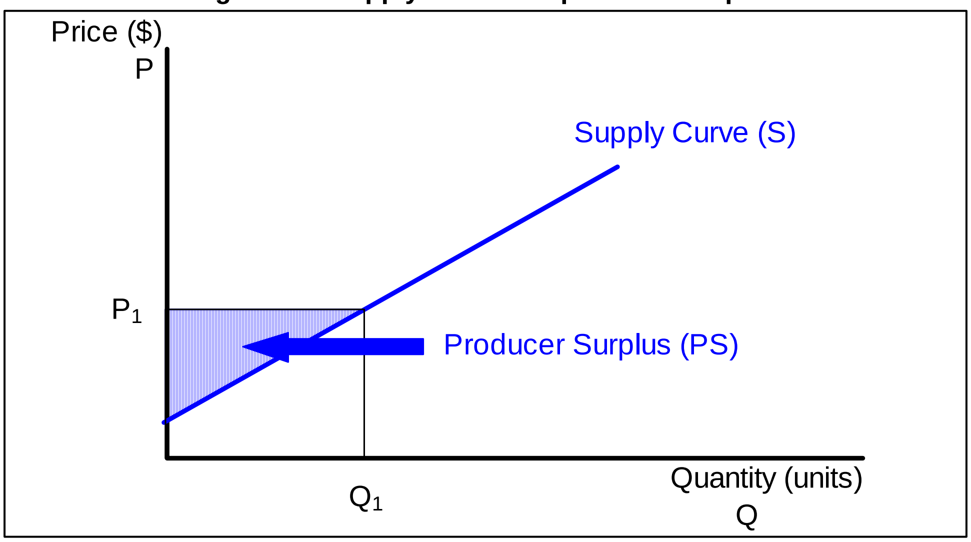


Supply Curve and Producer Surplus

The above discussion of consumer surplus refers to economic benefits (or savings) received by consumers of goods and services. Producers also receive economic benefits based upon the (windfall) profits they make from selling goods and services. The supply curve indicates how many units of a good or service producers are willing to produce and sell at a given price. As prices increases, producers generally want to produce and sell more goods, thus this curve slopes upward from left to right.

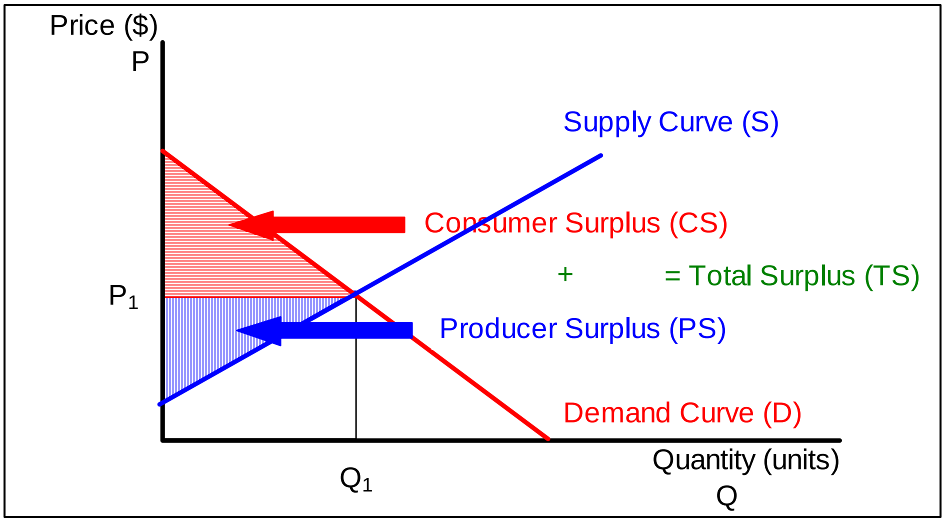
If producers receive a higher price than what it costs to produce the good, i.e. their willingness to accept for the good, then they receive an economic benefit (windfall profit) from the sale, called producer surplus. To estimate producer surplus, data are required on variable costs of production and revenues received from the good. P_1 and Q_1 in Figure A-2 indicate the current market price and the quantity sold. The shaded area illustrates producer surplus.

Figure A-2 Supply curve and producer surplus



Total economic benefit, or total surplus, is the sum of consumer and producer surplus. Figure A-3 illustrates both consumer and producer surplus based upon the intersection of the demand and supply curves.

Figure A-3 Consumer and producer surplus



Changes in Consumer and Producer Surplus

The economic benefit of an action to the persons who are buyers is measured by changes in consumer surplus, which changes if there is a change in the price or the quality of a good. For example, if the price of a good increases but a person's willingness to pay remains the same, the economic benefit received or consumer surplus—willingness to pay minus price—will be less than before. Or, if the quality of a good improves, but the price remains the same, a person's willingness to pay may increase thus the economic benefit will also increase. To estimate changes in consumer surplus, the demand curves for conditions before and after the action must be determined.

Alternatively, the economic benefit to consumers, or consumer surplus, can be affected by changes in the prices of other related goods. If goods can be *substituted* for each other, then if the price of one good declines while the prices of other similar goods and incomes remain the same, a consumer can increase his or her satisfaction by purchasing more of the good that has fallen in price and less of the other goods. For example, if coffee and tea are close substitutes, then if the price of coffee goes up, there may be more demand for tea. The demand curve for tea will shift upward to the right, increasing consumer surplus.

Conversely, if goods are *complementary*, then changes in the price of one good will lead to a change in the demand, and thus consumer surplus, for the other good. For example, if sugar is purchased and consumed along with coffee, then increases in prices for coffee (and thus reductions in its coffee consumption) may also result in less demand for sugar. Thus, the consumer surplus for sugar is also decreased because its demand curve is shifted downward to the left.

The economic benefit of an action to producers is measured by *changes* in producer surplus. These changes can occur because of changes in the availability and/or prices of goods and services used in the production process.

Figure A-4 and Figure A-5 show changes in total surplus, i.e. total economic benefits, resulting from shifts in the demand and supply curves. Economic benefits are a key input into benefit-cost analysis, which (as discussed in Chapter 3) is used to determine the economic justification of the project.

Figure A-4 Changes in total surplus due to increased demand

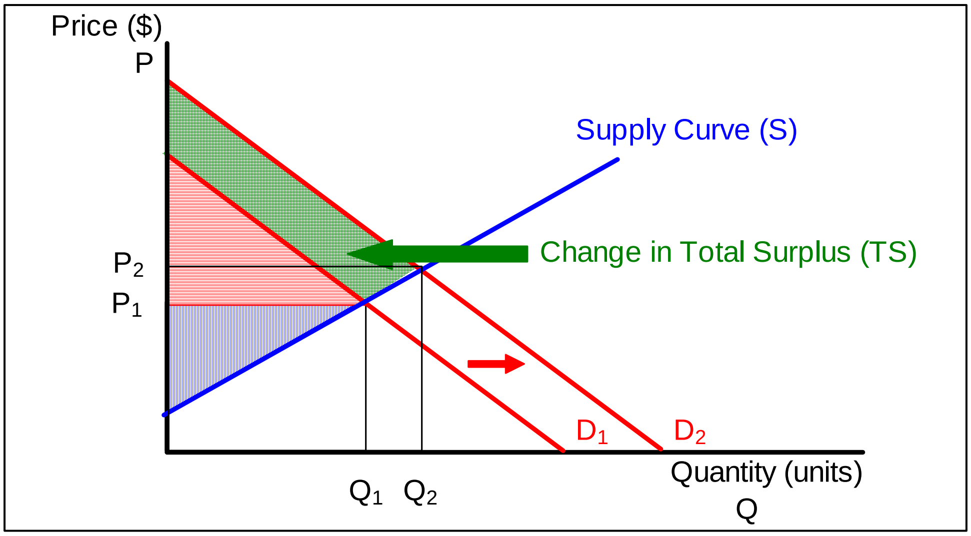
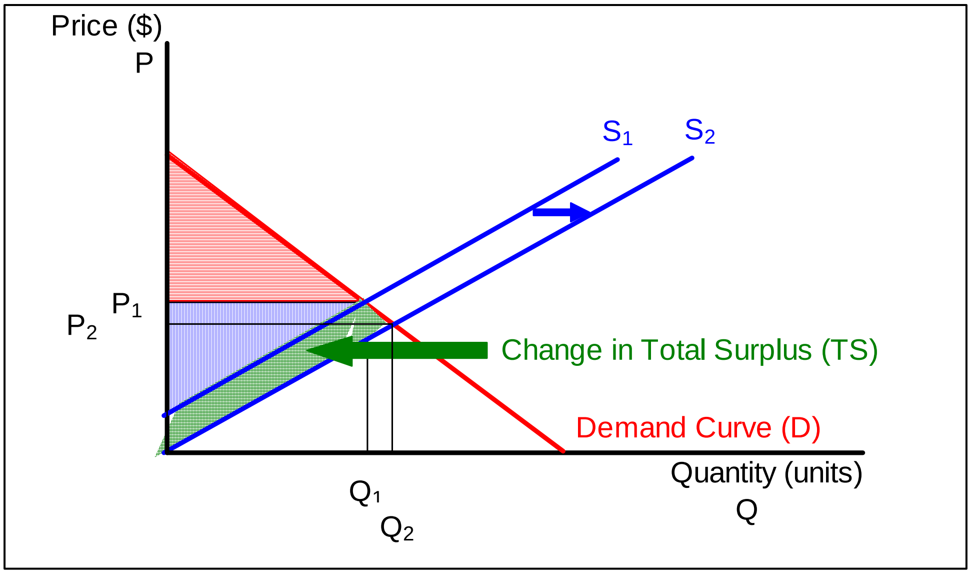


Figure A-5 Changes in total surplus due to increased supply



Other Issues

The above discussion of willingness to pay, willingness to accept, and the related concepts of consumer and producer surplus were simplified. A number of issues can complicate economic analyses, including:

- Pure competition vs. other market types: Figures A-4 and A-5 illustrate a purely competitive market structure with the following characteristics: (a) there are many buyers and sellers, and no individual can significantly affect the market price; (b) all the firms produce and sell identical or homogenous products; and (c) buyers and sellers have perfect information and are able to freely enter or leave the market. Obviously there are very few markets that meet these very restrictive conditions. Other market types include oligopoly (few major sellers) and monopoly (one seller). The concepts describe above still apply, although they would be graphed differently for these different market structures. Other market distortions may also be present, such as economic rent (described below) taxes, subsidies, transfer payments, and externalities.
- Economic rent: a market distortion can occur if a productive good or factor is fixed in amount regardless of price and therefore the supply curves shown in Figure A-4 and Figure A-5 would be vertical (i.e., inelastic) rather than upward sloping. Therefore, higher prices will not increase the supply of these fixed resources. All payments made (other than for maintenance and depreciation) for an asset whose supply curve is perfectly vertical and available without any cost of production are “economic rent.” Fixed resources yield economic rent because they are not only productive but because they are *scarce*. For example, with a vertical supply curve, increases in demand because of scarcity will raise the prices of the resource above what would be received for that resource based upon its productive capacity. The amount of “economic rent” received for a resource above its otherwise productivity potential should be excluded from benefit/costs analyses.
- Income vs. price effects: As illustrated above, shifts in the demand curve result in changes in consumer surplus, which provides the basis in measuring changes in consumer welfare. Although the goal is to measure changes in consumer surplus caused by price changes, there is concern among economists that the changes in consumer surplus include not only the effects of the price changes, but also the income effects that occur along with the price changes. (Any change in the price of a good generates two effects on the buyers, a price effect and an income effect.) Therefore, it may necessary to adjust for the income effects such that only price effects upon consumers are measured, which requires the derivation of “income adjusted” demand curves. This is very difficult to do, and some evidence suggests that there is not that much difference between the “adjusted” and “ordinary” demand curves.
- Income distribution: A consumer’s desire for a particular good or service must be backed up with income that can translate that desire into an actual willingness to pay. If the current distribution of income were changed, it is likely that the willingness to pay for different goods would also change because different people would then have the ability to purchase alternative goods and services. For example, environmentally related goods and services may be important to residents in a relatively low-income community, but because of the lower income levels these residents are unable to pay for these amenities.

  If the income distribution in this community were somehow changed, then it might be possible to translate this desire into an actual willingness to pay. However, because economists and other policy-makers have no way of determining which income distribution policy is superior; the current income distribution must be accepted for the benefit and cost analysis.

- Individual vs. social effects: The above discussion focuses upon demand and supply curves of individual consumers and producers. However, it is necessary to evaluate the impacts of changes in goods and services (especially public ones) upon society as a whole. Welfare economics is a branch of economics that focuses upon how a society can allocate scarce resources to maximize social welfare (economic efficiency).

  The *Pareto optimality* criterion suggests that an efficient allocation of resources occurs only when there are no possible reallocations that could make at least one person better off without making another worse off. With this criterion, efficiency cannot be achieved by a project if it makes just one person worse off than before, even if many more are made better off. Obviously, this is a very restrictive criterion, and reliance upon it would result in very few programs or projects being implemented because most involve trade-offs among individuals, with some benefiting while others losing. This is especially true for multi-objective water management plans that can affect entire watersheds and multiple stakeholders with diverse and competing interests.

  A less restrictive criterion is called *potential Pareto optimality* which states that an increase in general welfare occurs if those who are made worse off could in principle be compensated for their losses, whether or not this compensation occurs. This is this the criterion upon which benefit and cost analysis (described below) is based.

- Public vs. non-public goods: Many goods and services exist that can be consumed at the same time by more than one consumer and for which it is not feasible to restrict any consumer's access to those goods or services (that is, there are no markets). These are called "public goods." For example, a floodplain management proposal might include the restoration of natural wetland and riparian habitat, which can be enjoyed by all of the inhabitants of a community. Although there are no traditional markets for habitat, they can provide numerous benefits to society, and as discussed in Chapter 4, different measurement methods can be used to incorporate these values into a benefit/cost analysis.

- Measuring ecosystem outputs: To successfully place monetary values on ecosystem services, it is essential to be able to first measure the physical outputs from those ecosystems. Unfortunately, measuring the physical outputs from ecosystems can be more difficult than the process of attempting to place monetary values on ecosystem services.

Types of Values

Economists generally classify values as either *use* or *non-use* values. Use values include direct, indirect, option, and bequest values.

Direct use values contribute to consumer satisfaction or producer profits. For example, a restored wildlife preserve along a river creates values for those who visit the site to view wildlife or to those who harvest natural products (berries, fish, etc.) to be sold to others. Indirect use values are those that contribute to production or consumer utility by supporting other direct activities (or avoiding damages to those direct activities). For example, if the restored wildlife area also acts as a temporary floodwater storage site, then flood damage to downstream residential and commercial properties can be reduced. Option value is the value that people place on having the ability to enjoy something in the future, even though they may not currently use it. For example, a resident in a nearby community may not currently visit the restored wildlife area, but may plan to do so in the near future. Bequest value is the value that people place on something knowing that future generations will have the option to enjoy it. For example, another resident may not be planning on visiting the site, but it has value to them because their children may be able to visit the site in the future.

All of the above-mentioned values assume some sort of use—either now or in the future. However, it is also possible that a resident may value the restored wildlife area even if nobody can visit it (now or in the future); it has value simply because “it exists.” This is an example of a non-use existence value.

The fundamental problem facing economists is how to express all of these different types of values using a common monetary basis so that they can be directly compared to each other. While some of these values can be expressed relatively easily in monetary terms, others cannot. It is the latter group that poses special problems for economic analysis (particularly benefit/cost analysis), and methods to evaluate non-market values are discussed in Chapter 4.

‘Without’ vs. ‘With’ Project Conditions

Economic analysis (as well as all aspects of project evaluation) must focus upon the change in conditions expected to occur “without” the project vs. “with” the project. The “without” project conditions, which include not only historical and existing conditions but also future without-project conditions, become the baseline from which all project effects (positive and negative) are compared. Thus, the estimation of the existing and future without-project conditions is a critical step in the economic analysis. It not only involves the projection of key socioeconomic variables (such as population, employment, housing, etc.), but also other related projects that may become operational in the study period without the proposed project. Often the “without” vs. “with” comparison is confused with a “before” and an “after” comparison; this is not correct because some of the benefits forecasted to occur in the future with the project may also have occurred even without the project. Therefore they should not be attributed to the project.

Planning Time Horizons

In any feasibility study, different planning time horizons may be encountered. Typically these time horizons include:

- Economic life: The period in which the project is economically viable, which means that the incremental benefits of continued use exceed the incremental costs of that use.
- Physical life: The period in which the project can no longer physically perform its intended function. Economic life may be shorter than physical life but not vice versa.
- Period of analysis: The length of time over which a project’s consequences are included in a study. Typical analysis periods for structural water resource projects are 50 to 100 years and 5 to 25 years for nonstructural projects. If the period of analysis is not an even multiple of physical lives, an adjustment can be made using either a negative cash flow or salvage value. However, often such a detailed analysis is not warranted because of discounting (discussed below) since this adjustment occurs at the end of the analysis period.

  Within the analysis period, a base year must be identified which generally is when project construction/implementation occurs, and project outputs (that is, benefits) occur after the base year. The base year is usually called year 0 and subsequent years are numbered 1 through the end of the analysis period. If project construction occurs over several years, then these are included in the analysis period prior to the base year, and these are numbered -1, -2, -3, etc. Analysis years prior to the base year are treated differently in the discounting process than years occurring after the base year.

- Short term vs. long term: Short term is the period of time in which capital investments cannot be changed. For example, a community has invested in a local reservoir to augment its water supplies. While it may be able to vary deliveries from that reservoir, it cannot add additional water supply facilities over a short period of time. In contrast, over the long term, the community can adjust to changing local water demand and supply balances by adding new water supply facilities, such as an aqueduct importing supplies from other basins or the construction of a seawater desalination plant.
- Financing period: The length of time required for bond repayment or other required paybacks, which may be shorter or longer than the period of analysis. This time horizon is only relevant for financial analyses.

Analysis Perspectives

Economic analysis depends upon whose perspective is being taken in the evaluation. For example, a floodplain management project may remove crops currently in production along a river and restore the land for ecosystem restoration purposes that will affect numerous groups of people (stakeholders).

The growers will obviously be concerned with the loss of net income as their lands are removed from production. However, potential recreationists who might visit the restored area will be concerned with the quality and quantity of the restored habitat. A nearby community will be concerned about the potential losses to food processors, farm workers, farm suppliers, and others who will lose indirectly because of crops being removed from production. However, these losses would be partially offset by increased spending in the community from persons visiting the restoration area.

The community could also experience various fiscal effects, such as reductions in property taxes as private lands are converted to public ownership, loss of sales tax revenues from reduced sales of agricultural-related goods and services, and the potential for increased police and fire protection expenses necessitated by increased visitors to the restoration area. Some of these negative effects will be partially offset by increased sales tax revenue from visitors and reductions in flood response-related expenses. Collectively, all of these positive and negative indirect effects are sometimes called “third party impacts.” And finally, the nation will be interested in forgone investments elsewhere if funds are committed to a particular project, and possible changes in output elsewhere resulting from project induced production changes (for example, reduced visits to ecosystem restoration sites elsewhere that might occur if the proposed project were constructed).

One way or another, all of these effects can be included in an economic analysis. Some of these effects are direct effects (such as the loss of crop net income or the value of the habitat to recreationists) and would be included in a benefit-costs analysis to justify the project’s construction, assuming all benefits can be expressed in monetary terms. If they all cannot be expressed in monetary terms (for example, the value of the habitat), then the benefit-cost analysis may have to be combined with a trade-off analysis to evaluate the monetary gains and losses compared with physical changes in other types of project outputs (such as the quantity of habitat).

Many of the indirect effects (changes in sales of agricultural or recreational goods and services, changes in a community's fiscal conditions, etc.) can all be evaluated in an economic impact analysis, which can help decision-makers fully understand the consequences of their actions and can be disclosed in an environmental impact statement/report. If funding is to be obtained from the federal government, then the effect upon national economic development will also have to be taken into account. (See US Water Resources Council, *Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies*, March 10, 1983, Chapter II.)

Inflation and Escalation

Inflation is the rate of change in general price levels throughout the economy. Inflation is usually measured by a broad-based price index, such as the Consumer Price Index. Although inflation can be included in an economic analysis, it is generally recommended that it not be included because of the extreme uncertainties about forecasting future inflation, especially over long planning time horizons.

When inflation is excluded, prices levels are evaluated in real (or constant) dollars. However, for items that are expected to experience a change in price different than the general inflation rate, the differential rate can be included in an economic analysis. For example, if the annual inflation rate is 4% but energy costs are expected to increase 6% on an annual basis throughout the planning period, then the differential between the two price levels (2%) can be used to increase annual energy costs in the analysis. This differential is called an *escalation adjustment*.

Cost Indices

Cost or price indices are used to measure the relative change in the cost of a commodity (or groups of commodities) over time. Even though future inflation is usually excluded in economic analyses, it is still often necessary to convert dollar values from different time periods to one base year. For example, one cannot readily do a comparison of alternative projects' costs if one estimate was prepared in 2000 and the other in 2003. Although the 2003 cost estimate could be expressed in 2000 dollars, it is usually more common to bring the 2000 estimate up to current 2003 dollars by calculating the change in an appropriate cost index.

The most widely known price index is the Consumer Price Index (www.bls.gov/cpi/) that produces monthly data on changes in the prices paid by urban consumers for a representative basket of goods and services. However, this index is not appropriate for indexing water project construction costs. For indexing construction costs, indices include the Gross Domestic Product Implicit Price Deflator research.stlouisfed.org/fred2/series/GDPDEF/21), the US Bureau of Reclamation (Bureau) Construction Cost Indices (www.usbr.gov/pmts/estimate/cost_trend.html), the Engineering News-Record Construction Cost Index (enr.construction.com), or the US Army Corps of Engineers' (Corps) Civil Works Construction Cost Index System (www.usace.army.mil/inet/usace-docs/eng-manuals/em1110-2-1304/entire.pdf).[2] Producer Price Indexes can also be extremely valuable for agricultural and other commodities (www.bls.gov/ppi/home.htm and www.bls.gov/ppi/ppiesc.htm).

The use of the Gross Domestic Product Implicit Price Deflator is recommended to measure price changes for all goods and not just consumer goods.

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[2] The Corps' publication *Civil Works Construction Cost Index System* (EM 1110-2-1304; March 2000) provides an excellent discussion of how to use cost indices.

Adjusting for Different Time Periods (Discounting)

Because analyses of water resource projects typically encompass long periods of time, it is necessary to adjust for the time value of money. Even if there is no inflation, a dollar received today is worth more than one received in the future because a dollar received today can be put to immediate use. Adjusting for different time periods is accomplished by estimating the present value of each benefit and cost in the future.

Present values are calculated with a simple formula ($P = F / (1+r)^n$), which involves dividing the future dollar amount of benefit or cost by a discount factor $(1 + r)$ raised to the nth power. In this equation, P equals the present value of the future cash flow, F = future cash flow, r = discount rate, and n = number of time periods into the future that the benefit or cost occurs. Alternatively, present value “factors” for different discount rates and analysis years may be found in financial tables.

Discount Rate

The discount rate is used to adjust dollars received or spent at different times to dollars of a common value, usually present day dollars (“present worth” or “present value”). Although there are different methods for determining discount rates, generally the value to use for this rate is the real (that is, excluding inflation) rate of return that could be expected if the money were instead invested in another project. In other words, the discount rate is a measure of forgone investment opportunity (that is, “opportunity cost”) if the money allocated to the project were invested elsewhere.

The selection of a discount rate is critical for the analysis because the larger the discount rate, the greater the reduction in future monetary values. This tends to affect benefits more than costs because the majority of costs are incurred early in the analysis period (for example, construction costs); whereas, benefits typically occur later in the analysis period. DWR is currently using a 6% discount rate, which approximates the marginal pretax rate of return on an average investment in the private sector in recent years. This rate will be periodically reviewed and revised as necessary. The US Treasury Department annually sets the discount rate used by the Corps and the Bureau.[3] The discount rate is very much different from the bond repayment interest rate that is used in the financial analysis.

Present Value Analysis

A project’s benefits and costs typically occur over different time periods. For most projects or programs, construction or implementation costs occur up front in a project’s life, followed by smaller recurring annual operations and maintenance costs. In contrast, project benefits usually occur only after construction is completed, and they may gradually increase over time if a “build-out” period is required (for example, increasing water demand caused by increasing population growth). Because costs and benefits occur over different times, they cannot directly be summed and compared to each other but instead must be made comparable through a present value analysis.

In a present value analysis, all annual costs and benefits are discounted using the same discount rate, and total discounted benefits and costs can then be summed for the entire analysis period and directly compared to each other using a net benefit or B/C ratio analysis. The discounting occurs by multiplying

[3] The Corps discount rates are included in their Economic Guidelines Memorandum found on their General Planning Guidelines website: http://www.usace.army.mil/cw/cecw-cp/library/planlib.html

the present value factor times the appropriate benefit and cost data for each year. No discounting occurs for the base year (year 0), and decreasing present value factors are applied for succeeding years in the analysis period.

Forgone Investment Value

If construction occurs prior to the base year, then the future value of these expenditures must be determined by multiplying these monetary costs by a future value factor (which is the reciprocal of the present value factor). Often this future value adjustment is called "interest during construction;" however, this terminology is not correct because it implies that this adjustment reflects actual interest charges incurred prior to construction. While these interest charges do occur, they are accounted for using a different procedure (which takes into account compound interest) in a financial analysis. These future value adjustments are more appropriately called "forgone investment values" to reflect the value of other investments that could have been pursued if the project were not undertaken ("opportunity costs").

Example Present Value Analysis

An example present value analysis is presented in Table A-1 for a project with capital costs of $300,000. Project construction occurs over three years, which are shown as years -2, -1, and 0, with project benefits expected to occur for a 25-year period following construction. Prior to the base year, the annual construction costs are multiplied by a future value factor that effectively increases those costs. After construction, present value factors are multiplied times the annual operations and maintenance costs and the project benefit values, effectively reducing those values. Total discounted costs are about $572,200 compared to total discounted benefits of about $639,200. If a benefit/cost analysis is being conducted (described below), net benefits are equal to about $67,000 and the B/C ratio is about 1.12 (in other words, for every project dollar spent, benefits equal $1.12).

Another useful type of analysis computes the cost per unit (in this example, the cost per acre-foot of water deliveries). This is a cost-effectiveness analysis. In this example the cost per acre-foot is about $450. It should be noted that in addition to discounting project costs, the water deliveries are also discounted to keep them comparable to discounted costs.

In some cases it may be more useful to express benefits and costs in annual terms, which can be accomplished by multiplying total discounted benefits and/or costs by a capital recovery factor for the planning period to obtain average annual equivalents. Tables and formula for present value (discount) and capital recovery factors can be found in DWR's Draft *Economics Practices Manual* and most financial analysis textbooks. The B/C ratio would be the same whether total or annual discounted benefits and costs are used.

Life Cycle Cost Analysis

Life-cycle cost analysis (LCCA) is a method for assessing and comparing the total costs of alternatives. It takes into account all costs of acquiring, owning, and disposing of facilities and related equipment. LCCA is especially useful when project alternatives that fulfill the same performance requirements, but differ with respect to initial costs and operating costs, have to be compared in order to identify the one that maximizes net cost savings. The three key variables in a LCCA include identifying and evaluating for each alternative all pertinent costs, the period of time over which these costs can be compared, and the discount rate that is applied. The LCCA concepts are essentially the same as the cost analysis concepts included in this Guidebook. The key is identifying and collecting data for all "pertinent costs."

Table A-1 Example discounting analysis: Present and future values

	Year (a)	Discount factor (b)	Capital costs (c)	Operations & maintenance costs (d)	Total costs (e)	Discounted costs (f)	Water supply benefits (g)	Discounted water supply benefits (h)	Water deliveries (i)	Discounted water deliveries (j)
	-3	1.190	$0	-----	$0	$0	-----	-----	-----	-----
Future Value	-2	1.124	$70,000	-----	$70,000	$78,652	-----	-----	-----	-----
	-1	1.060	$130,000	-----	$130,000	$137,858	-----	-----	-----	-----
Base Year	0	1.000	$100,000	-----	$100,000	$100,000	-----	-----	-----	-----
	1	0.943	-----	$20,000	$20,000	$18,860	$50,000	$47,150	100	94
	2	0.890	-----	$20,000	$20,000	$17,800	$50,000	$44,500	100	89
	3	0.840	-----	$20,000	$20,000	$16,800	$50,000	$42,000	100	84
	4	0.792	-----	$20,000	$20,000	$15,840	$50,000	$39,600	100	79
	5	0.747	-----	$20,000	$20,000	$14,940	$50,000	$37,350	100	75
	6	0.705	-----	$20,000	$20,000	$14,100	$50,000	$35,250	100	71
	7	0.665	-----	$20,000	$20,000	$13,300	$50,000	$33,250	100	67
	8	0.627	-----	$20,000	$20,000	$12,540	$50,000	$31,350	100	63
	9	0.592	-----	$20,000	$20,000	$11,840	$50,000	$29,600	100	59
	10	0.558	-----	$20,000	$20,000	$11,160	$50,000	$27,900	100	56
	11	0.527	-----	$20,000	$20,000	$10,540	$50,000	$26,350	100	53
	12	0.497	-----	$20,000	$20,000	$9,940	$50,000	$24,850	100	50
	13	0.469	-----	$20,000	$20,000	$9,380	$50,000	$23,450	100	47
	14	0.442	-----	$20,000	$20,000	$8,840	$50,000	$22,100	100	44
	15	0.417	-----	$20,000	$20,000	$8,340	$50,000	$20,850	100	42
	16	0.394	-----	$20,000	$20,000	$7,880	$50,000	$19,700	100	39
	17	0.371	-----	$20,000	$20,000	$7,420	$50,000	$18,550	100	37
	18	0.350	-----	$20,000	$20,000	$7,000	$50,000	$17,500	100	35
	19	0.331	-----	$20,000	$20,000	$6,620	$50,000	$16,550	100	33
	20	0.312	-----	$20,000	$20,000	$6,240	$50,000	$15,600	100	31
	21	0.294	-----	$20,000	$20,000	$5,880	$50,000	$14,700	100	29
Present Value	22	0.278	-----	$20,000	$20,000	$5,560	$50,000	$13,900	100	28
	23	0.262	-----	$20,000	$20,000	$5,240	$50,000	$13,100	100	26
	24	0.247	-----	$20,000	$20,000	$4,940	$50,000	$12,350	100	25
	25	0.233	-----	$20,000	$20,000	$4,660	$50,000	$11,650	100	23
	Total		$300,000	$500,000	$800,000	$572,170	$1,250,000	$639,150	2,500	1,278

Total Present Value (6%; 25 years) $572,170 $639,150

Average Annual Equivalents (6%; 25 years; CRF = 0.0782) $44,744 $49,982

Net Benefits = Total Discounted Benefits - Total Discounted Costs = $66,980

Benefit/Cost Ratio = Total (or Annual) Discounted Benefits/Total (or Annual) Discounted Costs = 1.12

Cost/AF = Total (or Annual) Discounted Costs/Total (or Annual) Discounted Deliveries = $448

Risk and Uncertainty

Risk and uncertainty are intrinsic in water resources planning and design and are defined by the National Research Council as follows:

> "*Risk*" is generally understood to describe the probability that some undesirable event occurs, and is sometimes used to describe the combination of that probability and the corresponding consequence of the event. The Corps measures risk by the probability that a levee fails or that an ecosystem restoration project fails to meet a standard. The complement of risk is *reliability*; the probability that a system operates without failing. The term "*uncertainty*" should be used to describe situations without sureness, whether or not described by a probability distribution.[4]

All measured or estimated values in project planning and design are to various degrees inaccurate due to sampling, measurement, estimation, forecasting, and modeling errors. Invariably the "true" values are different from any single point values currently used in many planning studies. The federal *Economics and Environmental Principles and Guideline for Water and Related Land Resources Implementation Studies* requires that planners characterize, to the extent possible, the different degrees of risk and uncertainty inherent in water resources planning and to describe them clearly so decisions can be based on the best available information. The Corps is a leading proponent of "risk-based analysis," which attempts to analytically incorporate considerations of risk and uncertainty.

Sources of Risk and Uncertainty

There are two key sources of uncertainty in a planning study—model specification and data collection and measurement. The first arises because of the incredibly complex physical, social, and economic conditions and the inability to specify models that accurately portray them. Even if these models could be accurately specified, there can be considerable uncertainty in the collection and measurement of data that describe these conditions. For example, consider the following variable uncertainties encountered in a typical flood damage reduction study:

> Economic variables in an urban situation may include, but are not necessarily limited to, depth-damage curves, structure values, content values, structure first-floor elevations, structure types, flood warning times, and flood evacuation effectiveness. Other types of variables may be important for other types of projects. For example, in agricultural areas seasonality of flooding and cropping practices may be important. The uncertainty of these variables may be due to sampling, measurement, estimation, forecasting, and modeling errors. For hydrologic and hydraulic analysis, the principle variables are discharge and stage. Uncertainty in discharge exists because record lengths are often short or do not exist where needed, precipitation-runoff computation methods are inaccurate, and the effectiveness of flood flow regulation measures is not precisely known. Uncertainty factors that affect stage might include conveyance roughness, cross-section geometry, debris accumulation, ice effects, sediment transport, flow regime, bed form, and others. For geotechnical and structural analysis, the principle source of uncertainty is the structural performance of an existing levee.

[4] NRC, *Risk Analysis and Uncertainty in Flood Damage Reduction Studies*, Chapter 3.

Uncertainty in structural performance occurs due to a levee's physical characteristics and construction quality. These, in turn, influence the Probable Non-failure (PNP) and Probable Failure Point (PFP) required in the reliability assessment of existing levees.[5]

Accounting for Risk and Uncertainty

Although it is impossible to account for all sorts of uncertainty and risk in a planning study, there are techniques that can be used to acknowledge their existence and to assign some quantitative importance to them in the analysis. These techniques include direct enumeration, sensitivity analysis, probability analysis, game theory, and in some cases, stochastic simulation.

- Direct enumeration. With this technique, all possible outcomes are listed. While this would provide decision-makers an idea of the possible outcomes of an action, it doesn't provide any clue as to the probability of one event happening over another. Also, given the complex relationships that are involved in most water resource related studies, all possible outcomes are not likely to be known.
- Sensitivity analysis. In sensitivity analysis, the values of key variables can be varied to determine their effects upon the variables being analyzed. A good example of this would be to vary the discount rate used for computing the present worth of benefits and costs of a proposed project. If the different discount rates do not have a significant effect upon the results, the analyst may feel more comfortable with the results than otherwise. Although sensitivity analysis is relatively easy to do, it has numerous drawbacks: (a) it frequently assumes that the appropriate range of values is identified and that all values are equally likely to occur, (b) the results of the analysis are often reported as a single, most likely value that is considered as perfectly accurate.
- Probability analysis. Although it is recognized that the "true" values of planning and design variables and parameters are not known with certainty and can take on a range of values, it may be possible to describe a variable or parameter in terms of a probability distribution. For example, for a normally distributed variable or parameter, indicators such as mean and variance can be identified which would allow confidence intervals to be placed around point estimates. In other words, instead of saying the B/C ratio for a project is 1.20, we might be able to say that we are 90% confident that the B/C ratio exceeds the value of 1.15, which gives the decision-makers more information to consider.
- Stochastic simulation. This is also known as Monte Carlo simulation or model sampling. An example of this type of analysis is the Corps' software program, HEC- FDA (Flood Damage Assessment) that directly incorporates uncertainties into a flood damage analysis. For example, direct inputs into this program include frequency/discharge, stage/discharge and structural inventories for which stage/damage curves are determined within the program. FDA statistically assigns error bands around all of these relationships, and then through a Monte Carlo analysis, samples within the various relationships' error bands in order to determine expected annual damage. Although this program is still subject to the same fundamental sources of uncertainty (model specification and data collection/measurement), at least it explicitly attempts to incorporate uncertainty into the flood damage analysis.

[5] USACE, Engineering Regulation 1105-2-101, *Risk-Based Analysis for Evaluation of Hydrology/Hydraulics, Geotechnical Stability, and Economics in Flood Damage Reduction Studies*, March 1, 1996.

An excellent example of a risk-based analysis is the Delta Risk Management Strategy (DRMS) currently being conducted by DWR, the Corps and other agencies. Objectives of DRMS include:

- Evaluate the risk and consequences to the state (e.g., water export disruption and economic impact) and the Sacramento-San Joaquin Rivers Delta (e.g., levees, infrastructure, and ecosystem) associated with the failure of Delta levees and other assets considering their exposure to all hazards (seismic, flood, subsidence, seepage, sea level rise, etc.) under present as well as foreseeable future conditions. The evaluation shall assess the total risk as well as breaking the risk down for individual islands.
- Propose risk criteria for consideration of alternative risk management strategies and for use in management of the Delta and the implementation of risk-informed policies.
- Develop a DRMS, including a prioritized list of actions to reduce and manage the risks of consequences associated with Delta levee failure.

Figure A-6 illustrates the major components of the DRMS risk model. For more information on DRMS, visit the website at http://www.drms.water.ca.gov/.

Figure A-6 DRMS Risk Model